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Large Rapidity Gaps between Jets at HERA and at the Tevatron

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Abstract

In this talk I consider the formation of a rapidity gap in hadron production between two jets.

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Rapidity gaps in hadron production between two jets have been observed in photoproduction at HERA [1] and in $p\,\bar{p}$ collisions at the Tevatron [2], where it was found that collecting events with two or more jets and ranking them according to the rapidity interval $\Delta\eta$ between the two jets with the largest transverse energy (leading E_T jets), roughly 1 % of the events showed a gap in particle production between the leading E_T jets. The ZEUS Collaboration [1] has observed the same phenomenon in photoproduction, but at a higher rate (roughly 7 % of the events show a gap).

The original theoretical motivation for examining two-jet production with a rapidity gap was to find a clear signal in $p\,p$ collisions at the SSC/LHC Colliders for the production of a Higgs boson heavy enough to decay to a pair of W or Z bosons. The leading Higgs-boson production mode is via gluon-gluon fusion, however it will be very difficult to distinguish the signal from the $t\,\bar{t}$ and $W\,W$ QCD backgrounds. The $W\,W \to H$ production rate is typically smaller, but it shows a distinct pattern of soft-hadron and minijet production in the central-rapidity region, since it is characterized at the parton level by color-singlet exchange in the cross channel [3, 4].

Accordingly, as a preliminary investigation it has been proposed [4] the study of color-singlet exchange between two partons, which can be carried over at the existing colliders. At the parton level the formation of a rapidity gap may be realized via the exchange in the cross channel of either an electroweak boson or of two gluons in a color-singlet configuration, which occurs at $\mathcal{O}(\alpha_s^4)$. However, the gap-production rate due to electroweak-boson exchange is in this case rather small and can be neglected [5].

The exchange of a gluon, which is an $\mathcal{O}(\alpha_s^2)$ process, constitutes the background. The probability for it to yield a rapidity gap is suppressed by a Sudakov form factor which makes it fall off exponentially as the rapidity gap between the partons widens, because the exchanged gluon is likely to radiate off more gluons in the gap [6]. Therefore a rapidity gap between two partons is an indication for a strongly interacting color-singlet exchange. Bjorken [4] estimated that $\hat{f}_{gap} \equiv \hat{\sigma}_{sing}/\hat{\sigma}_{oct} \sim 0.1$.

However, to produce a gap at the parton level is not sufficient because in the hadronization the gap is usually filled by the hadrons emitted in the spectator-parton interactions of the underlying event. Bjorken [4] estimated the rapidity-gap survival probability, $< |S^2| >$, to be about 5-10%. In a first approximation we can then assume that the fraction of two-jet events with a gap in soft-hadron production is given by $f_{gap} \simeq < |S^2| > \hat{f}_{gap}$. Thus gaps were predicted at about the 1% level [4], in qualitative agreement with the Tevatron experiments [2]. In photoproduction, though, the ZEUS Collaboration [1] observes gaps at about the 7% level. There are two possible explanations for the difference: at the hadron level $< |S^2| >$ is expected to increase as the c.m. energy $\sqrt{s}$ decreases [4, 7], and $\sqrt{s_{\gamma p}}$ at HERA is about an order of magnitude smaller than $\sqrt{s_{\bar{p}p}}$ at the Tevatron; at the parton level there are contributions to the gap from a resolved photon, for which two-gluon exchange is just like in $\bar{p}\,p$ collisions, and from a direct photon, which splits into a $q\,\bar{q}$ pair which then exchanges two gluons with a parton within the proton. Both contributions are $\mathcal{O}(\alpha_s^4)$, and mix together. The direct-photon component, though, has $< |S^2| >= 1$ since the photon is point-like. The combination of

these two effects may account for the difference between the gap rate at HERA and at the Tevatron. Any quantitative analysis, though, is not possible until $\mathcal{O}(\alpha_s^4)$ calculations are carried out in detail.

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